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Challenges and key patterns

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Viewing engineering offshoring in a network perspective: Challenges and key patterns

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Abstract
Companies are increasingly engaging with global engineering networks through offshoring of product development activities. This presents companies with many new challenges. The global engineering network (GEN) framework has been created to address the increasing dispersion of engineering activities across geographical and ownership boundaries. By using the GEN framework in studying engineering offshoring issues, the challenges faced by companies can be explained as a mismatch between the required capabilities and the companies' ability to deliver these capabilities. This paper provides new theoretical insight into both engineering offshoring and global engineering networks theories by extending the GEN framework.

Keywords: Global Engineering Networks (GEN), Engineering offshoring

Introduction
Companies are increasingly globalising their engineering activities through global networking alliances and by moving tasks to engineering facilities abroad (EIU, 2004; Chiesa, 2000). The first is termed *outsourcing* and the latter *offshoring*. The motivation includes cost savings, market access or gaining specific competences (Ferdows, 1997). These global engineering operations have led to new challenges, e.g. physical and cultural – and sometimes organisational - distance between teams and engineering operations. Few companies know how to evaluate risks such as these associated with moving functions and tasks offshore (Kumar *et al*., 2009). The literature on engineering offshoring has mainly been focused on product design or management of engineering. The global engineering network (GEN) framework presents an overall approach wherein to analysing the configuration and capabilities of global engineering networks. However, there is a gap in the literature as GEN has not been used in connection with engineering offshoring. In this manner engineering offshoring and the network perspective haven't been fully explored. This paper therefore targets at this know gap through investigating

how these complications with engineering offshoring can be addressed and resolved using the GEN framework.

Background & Relevant Literature

Global product development started in the 1990s and is still a relatively new phenomenon. Changes in market, technology and market preference have led to companies seeking to reduce development costs, improve development quality, and shorten development time (McDonough *et al*., 2001; Sanchez and Perez, 2003). Today, many manufacturing companies offshore not only production but also large parts of their product development process (Von Zedtwitz; 2002; Perks *et al*., 2005).

The key difference with engineering offshoring is the increased reliance on virtual collaboration across time zones and cultures. Frequently encountered problems include cultural differences, time zone differences, knowledge transfer, employee retention, and intellectual property protection (Rottman and Lacity, 2008; Kotlarsky *et al*., 2008; Carmel *et al*, 2005) . This is supported by Carmel & Beulen (2005) who found that unsuccessful knowledge transfer is one of the principal reasons for failure. Culture is a big risk factor as it influences communication, quality, knowledge sharing and many other aspects of management (Kull and Wacker, 2010; Hall, 1976). A Danish survey (2004) uncovered the main barriers to engineering offshoring experienced by Danish companies, which included communication difficulties, cultural differences, unforeseen costs, large travel costs and internal opposition to outsourcing. Offshoring-specific risks include managing local staff and local market needs, and culture as well as organisational risks (Lord & Ranft, 2000). Developing, exploiting and transferring knowledge across organizational units is critical for success (Gupta and Govindarajan, 2000). A major challenge is to manage local knowledge integration (Williams, 2007; Saka, 2004). Chen *et al.* (2010) showed that knowledge tacitness, knowledge gaps, cultural and communication difficulties and weak relationships were the critical barriers in cross-cultural knowledge transfer, which is confirmed by other researchers (e.g. Bhagat *et al*., 2002; Gonzalez *et al.*, 2006).

These complications are often due to the interaction intensity and interaction distance between the company and the organisational unit (Stringefellow *et al*, 2008). Interaction intensity consists of service content and service process. Interaction distance is based on the distance between cultures, languages and geographical distance. By evaluating the degree of interaction distance and interaction intensity, a company can evaluate whether to move a given task to a given location. Manufacturing companies which offshore high level engineering tasks like product development, product design and R&D activities to low-cost countries create a situation in which there is a high degree of interaction intensity which emphasises the risks involved with engineering offshoring.

The concept of global engineering networks (GEN) has been developed to address the increasing dispersion of engineering activities across geographical and ownership boundaries. Zhang, et al. (2006) identified the *characteristics* of effective engineering networks in the aspects of global engineering operations, engineering knowledge management, networked resources, and IT support and integration. Zhang, et al. (2008) revealed the *evolutionary trends* towards global engineering networks by investigating the major drivers, main barriers, organisational features, and performance preferences. Zhang, et al. (2007) proposed a systematic approach to understanding global engineering networks through investigating their contextual features, critical capabilities to success in a contextual circumstance, and configuration characteristics to deliver the capabilities. The essential elements of global engineering networks have been summarised with the context-capability-configuration (3Cs) framework, which is embedded in the strategic management theories and the operations management literature, especially the contingency theories (Sousa & Voss 2008), the configuration theories (Boyer, et al. 2000), and the theories of organizational or operational capabilities (Shi & Gregory 1998; Voss 2005). This contributes to an overall understanding of engineering off-shoring issues in the current business environment.

Zhang, et al. (2007) identified three key missions of global engineering networks, i.e. to gain global efficiency, to develop innovative products/services, and to improve strategic flexibility; and suggested four main capability areas to achieve the above missions: communication & sharing, integration & synergising, innovation & learning, and adaptation & restructuring.

With a configuration view, organisational features of engineering network operations can be systematically described by the following five configuration factors (Zhang & Gregory 2011).

- Network structures: referring to the physical footprint of resources, including the size, number, types/roles of network members, and the rationale of network design.
- Operations processes: referring to the flow of material and information between network members to create valuable output to customers.
- Governance systems: referring to the mechanisms to direct and control the network, including authority structures, performance measurement and coordination mechanisms.
- Support infrastructure: referring to enablers for network members to work together, including information systems, tools, resources, cultures and behaviours.
- External relationships: referring to the interaction with external partners, including suppliers, customers, users and collaborators.

Based on the above literature, we designed this research to extend the GEN framework from the strategic management and OM domains to address risks in engineering offshoring, to develop a more holistic view of global engineering networks today. This facilitates:

- A potentially more comprehensive definition of global engineering networks
- A potentially more complete understanding of the complexity of engineering offshoring
- An alignment between research within global engineering networks in the OM literature and engineering offshoring within product design and management literature

The ability to address risks in engineering offshoring using the global engineering networks framework may help improve the overall coherence of the business model, and also reveal potential improvements to the understanding of global engineering networks where unique elements are needed in order to address engineering offshoring within a network perspective. The main research question, therefore, is: "*How can offshoring of engineering tasks be explained and managed using the GEN framework?*"

Methodology

This research is cross-disciplinary with focus on both technical and organisational aspects and is a result of a collaboration between two European based Universities.
The research design is based on the research approach developed by Blessing & Chakrabarti (2002) (see Figure 1), which includes a descriptive and a prescriptive phase. Key elements of the research aim are to uncover the research object including both the present situation and possible improvement.

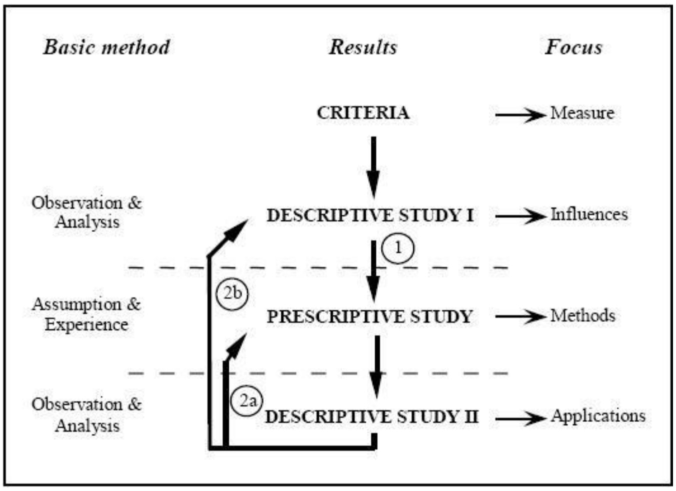

Figure 1 - The research approach. Source: Blessing & Chakrabarti (2002)

In the first phase an extensive literature review was carried out and a preliminary framework developed. In the second phase data was gathered from case companies to enrich and enhance this framework. In the third phase the framework was enriched with this input and in the last phase this framework was tested in industry consistent to the descriptive and prescriptive phases above.

The case study approach was selected as the most appropriate research method due to the complex and explorative nature of the research question as it allows for in-depth understanding of the research object. Case companies were selected based on a number of key criteria, including(i) the company were an engineering company with a large engineering department, (ii) had a global footprint, (iii) were from different sectors, to get breath and width in the dataset as well as possible access to top management. Four Danish multinational engineering corporations were selected with the above criteria. The case companies were from different sectors and were among the largest engineering corporations in Denmark. All these corporations had gradually globalised their engineering networks, starting with what they perceived as the least value adding activities. While global technology providers (e.g. universities, customers, suppliers) had been used for a long time these companies had in recent years started to globalise engineering activities through offshoring and outsourcing as a way to gain access to markets and unique capabilities while keeping costs down.

Interviewees were selected based on their experience with the company's global engineering activities. Vice presidents and managers for all areas were interviewed to understand the connectivity of the engineering activities with other functional areas. Data was collected through semi-structured interviews and lasted between 1-2 hours. Additional information came from company documentation and public statements. In total 39 interviews were carried out. All interviews were audio recorded and transcribed. Main data analysis approaches were coding (Strauss and Corbin, 1998) and pattern-matching (Yin, 1994). The codes were based on the interview guide and followed the themes from this. Each category was a theme in the interview guide, while each code – and subcodes if it was needed to divide the codes further - was the range of possible answers received. Condensation and ad hoc methods like creating new coding categories from the dataset were employed when necessary.

Case Studies and Key Findings

The case companies were among the largest and oldest engineering companies in Denmark. Through restructuring and focus on core competences in the 1990's these companies have experienced both organic growth and growth through M&As. Their main markets have over the years changed from Western markets to the emerging markets in for example China and India. They represent a wide selection of industries; pharmaceuticals, electronics, raw materials and energy. Over recent years they have all started to offshore and outsource to gain engineering competences not found in-house or for a cheaper price. As a result, their engineering centres are located around the world and the product development process consists of both local as well as global products which need to be coordinated. The following table show the key findings from the four case companies (table 2).

Table 2 - Findings from the case studies

	Network structure and Challenges after engineering offshoring	Supporting configuration dimensions to address offshoring risks
Company 1 **Description**: A more than 100 years old formerly family owned enterprise which is world-leading in the cement industry	There are 4 global engineering centres located in the USA, India Denmark. Key challenges are to ensure coordination, knowledge sharing, communication and transparency. The product's features were vital in how these challenges were felt. A legacy of some of these centres having been created due to an M&A means some resentment and different work approaches exist. Due to a centralised history exploring local networks is slow. Local policy in India and an already established office there has meant the company have moved more than 80% of all engineering tasks and more than 15% of all R&D to India from other global offices, with more expected to follow. However, it is mainly the Danish headquarters which have contact with outside knowledge providers like Universities etc. The company keeps a small manufacturing site they own to be able to 'test' R&D ideas in practice after all other manufacturing were outsourced.	Knowledge sharing and communication are important. Trust is a key element which is influenced by company ownership and equality structures as well as understanding of local culture and work approaches. Local policy making and brown field sites for engineering also influence the structure of the engineering network. Product features were important in regard to how easy it was to work on the product globally and how. Contact to manufacturing is important due to the large amount of parts which need to fit together. This interaction is thereby influenced by the product's features.
Company 2 **Description**: A more than 100 years old company which is world-leading in the telecommunications industry	Engineering is in Denmark and China with strategic partners in India. The relationship with the company in India is focused on competences and built on trust. Issues with the Chinese office include trust, knowledge sharing and coordination. Product features are important in how these issues were felt. The local network in China finds lower tier manufacturing suppliers. Contact to production and design engineers is needed to ensure a fast development process with many iterations. Due to IP rights and focus on western customers, the earliest stages of engineering (idea generation and sales) remains in Denmark as does contact with outside knowledge providers like Universities. Project features like size and perceived value influence work approach and interaction.	IP rights, trust and the market strategy influence the assignments and the power each unit has. Contact to outside knowledge providers remains with engineering in the headquarters. Some engineering units need communication and knowledge sharing with other areas like production engineers. Most manufacturing is outsourced but the company still owns a factory in China. Product features and project characteristics were important in regard to how easy it was to work on the product globally and how.
Company 3 **Description**: A sister company to a more than 100 years old family owned company which is world-leading as engineering	Cultural differences make communication and knowledge sharing between the unit in China and Denmark difficult. Expatriates have been used as a temporary solution. Embeddedness of the company strategy relating to global engineering is low with several processes, including HR, working against it. Product features, including complexity and modularity, were important in determining how easy it was to work with the task in a global network. Contact with all stages of development is important to ensure the final product agrees with laws and	The level of embeddedness of the engineering strategy in organisational routines, processes and practices influence how well it is carried out on the operational level. Furthermore, the level of cultural difference between organisational units and groups play a key role in what knowledge is shared and how. Strict rules and laws in many countries regarding

and consulting company within pharma and biotech.	regulations.	pharma and biotech means the company's development process is very integrated, from R&D to manufacturing.
Company 4 **Description**: Started 30 years ago, this company is now world leading within renewable energy	Have R&D and engineering facilities in 7 countries. IP rights are an issue with the new Chinese facilities. Danish managers are used to safeguard information. They are thereby an 'isolated' part of the network. This limits communication, trust and knowledge sharing. Product features were important in determining collaboration and task assignments.	IP rights and trust can influence how work processes are carried out and what work is given to which unit in the network, the level of knowledge sharing and collaboration and thereby influence the degree of integration in the network.

The case studies showed that engineering offshoring present companies with challenges related to communication and knowledge sharing which is addressed through official and unofficial knowledge sharing and communication as well as a more streamlined operation. However, this did not remove the challenges.

The GEN framework suggests that there need to be a match between network contexts, capabilities and configurations. The capabilities are a result of 4 elements (1) Communication and sharing within the GEN, (2) Integration and synergizing within the GEN, (3) Innovation and learning within the GEN and (4) Adaptation and restructuring within the GEN. Configuration is a result of the following 5 elements (1) Network structures of the GEN, (2) Operations processes for the GEN, (3) Governance system for the GEN, (4) Support infrastructure for the GEN, and (5) external relationships of the GEN. The mismatch in these case studies seemed mainly between the capabilities and the configuration characteristics which can explain the challenges the companies faced (see table 3).

Table 3 - Findings from the case studies mapped to the GEN framework

	Capabilities and configuration characteristics according to the *GEN framework elements*	Cause for complications
Company 1: Producer to the raw minerals industry	Communication and knowledge sharing is increasingly being documented and streamlined. Integration is done through top-down management from the headquarters. Innovation and learning is sought to be worldwide but is currently mainly isolated to each location. The network structure consists of several engineering locations in the USA, India and Denmark. Coordination is mainly through documentation, portals and telecommunications. Governance is through stage gates for each project. Support systems are telecommunications and online document sharing.	There is a lack of transparency between the engineering units due to the separation caused by the heavy reliance on documentation and top-down management. The current coordination mechanisms are therefore not suited for a situation where complicated knowledge has to be shared virtually. Furthermore, the governance system is not global or unifying which further emphasises this point. Finally, the support system does not allow for innovation and sharing in its current use with a top-down focus from the headquarters.
Company 2: Telecommunications industry	Communication and knowledge sharing is a mixture of documentation and exchange programs and visits. Integration is done through top-down management from the headquarters. Innovation and learning is sought to be worldwide but is currently mainly from the headquarters to each location. The network structure consists of several engineering locations in the USA, China and Denmark. Coordination is mainly through documentation, portals and telecommunications. Governance is through project run-throughs after they have completed. Support systems are telecommunications and	The current coordination mechanisms are well suited to the situation. However, governance is again project-based and local. Furthermore, knowledge sharing structures are still mainly one-way from the headquarters to the other engineering locations. This limits innovation and learning. Furthermore, the current support system is more oriented towards check-ups than two-way knowledge sharing.

	online document sharing.	
Company 3: pharma and biotech producer	Communication and knowledge sharing is through documentation and expatriates. Integration is done through top-down management from the headquarters, often via expatriates. Innovation and learning is sought to be worldwide but is currently from the headquarters to each location. The network structure consists of engineering locations in the USA, China and Denmark. Coordination is mainly through documentation, portals, telecommunications and expatriation. Governance is through stage gates through the project. Support systems are telecommunications, online document sharing and exchange programs.	Using expatriation ensures knowledge transfer and control over the project. However, it does not fulfil the company's desire to reduce costs through the use of Chinese engineers. Governance systems are project based which limits the company's desire for global knowledge sharing.
Company 4: Renewable energy product producer	Communication and knowledge sharing is through documentation and expatriates. Integration is done through top-down management from the headquarters and several security and control mechanisms are in place. Innovation and learning is sought to be worldwide but is currently from the headquarters to each location. The network structure consists of engineering locations in 7 countries. Coordination is mainly through documentation, portals, telecommunications and expatriation. Governance is through stage gates throughout the project. Support systems are telecommunications, online document sharing and expatriation.	Project based governance and heavy top-down control from the headquarters limits learning and innovation. Furthermore, the current coordination mechanisms are top-down which limits integration.

For case company 1 the needed capabilities included global innovation and learning as well as integration between the engineering units. However, the current configuration consists of global distributed units where coordination is mainly done through documentation and top-down communication in each unit. Furthermore, the governance system is project based and the support system is oriented towards one-way communication. The company's current configuration therefore does not support the desired capabilities which can explain the challenges the company faced in engineering offshoring. For case company 2 the needed capabilities are similar to case company 1 but the current configuration is better matched. Communication and knowledge sharing is a mixture of documentation, exchange programs and visits which encourages knowledge transfer and learning. However, coordination is still mainly top-down and controlled from the headquarters and governance is project based and local. Furthermore, the current support system is more oriented towards check-ups than two-way knowledge sharing. The current configuration therefore does not fully support the desired capabilities. In case company 3 there is a growing market in the developing world as well as cost pressures to deliver cheaper projects. The company wishes to develop capabilities to address local needs using one global approach, address cost pressures and share knowledge globally. The physical location is well suited for each market need with the Chinese office expanding. Communication between locations is limited and is on a project basis. Communication and knowledge sharing is through documentation and expatriates. The company is increasingly creating IT tools for knowledge sharing and coordination; however these are rarely used. Organisational structures encourage a focus on 'billing hours' to the client and on possessing valuable knowledge. The current configuration therefore does not deliver the needed capabilities. In case company 4 the company desires a global product development process with collaboration and integration and has opened new product development centres in key upcoming markets. Support systems like IT tools are not accessible to the Chinese engineers due to fear of losing IP rights, which makes knowledge sharing difficult. Communication is mainly from the headquarters and out, making it difficult for the subsidiaries to participate actively in innovation and learning.

Observations from the case studies suggest that if the desired capabilities can be delivered using modularity and a hand-over/arms-length transition, the organisation finds it easier to create the needed configuration. However, a truly integrated approach can be hindered due to organisational structures encouraging other capabilities.

Using the GEN framework, the difficulties that the companies faced can be explained as a result of a mismatch between the contextual features, critical capabilities needed to succeed in a contextual circumstance, and the company's configuration characteristics to deliver these capabilities. Mainly it seems the contextual features, the market needs and customer requirements had changed quickly in recent years. This has meant that new capabilities were needed. However, the companies were slow in change all the configuration characteristics. The network structure often fitted the capabilities in size, number and location. However, the role division was often out-dated with main power lying with the headquarters and subsidiaries which were previously in strong markets but were now in secondary markets (for example the US offices for case company 3). The operations processes were often a critical point. Information was frequently one-way and focused on input. Governance systems were often also not suited to the new capabilities and reflected old structures. Furthermore, it was often that clear performance measurements were lacking and the main focus was only on the given project. Support infrastructure in terms of IT and other technical tools were well developed in the cases. However, the organisational culture and behaviours would often result in these not being used as intended. External relationships were also well matched with case companies working with suppliers, customers and other external stakeholders.

These observations indicate that the GEN framework can be used to explain and manage the challenges with engineering offshoring. The GEN framework can be expanded to address these challenges so that companies can ensure a match between their desired capabilities and the configuration of their offshore engineering activities.

For engineering managers working with offshoring these findings mean that an analysis using the GEN framework can be useful as it can discover a potential mismatch between desired capabilities and the current configuration. This would allow managers to see engineering offshoring in a wider organisational perspective and thus make changes to the configuration so the desired capabilities can be delivered.

Conclusion

This article expands on engineering offshoring literature by providing a detailed description of the cause for risks and complications in engineering offshoring by using the global engineering network (GEN) framework. It expands the theoretical understanding of global engineering networks by illustrating how the GEN network can be used to explain and manage challenges within engineering offshoring.

The findings showed that the cause for complications with engineering offshoring can be explained as a mismatch between the required capabilities and the companies' ability to deliver these capabilities.

These findings suggest that offshoring engineering activities should first take place after an investigation has shown how capabilities and network configuration can be aligned so the company can deliver the capabilities it will need in the new environment.

These findings show the wide application of the GEN framework and can help expand the engineering offshoring literature as well. This research can, combined with previous research on global engineering networks, help create a more holistic view of the different global engineering networks a multinational corporation engages in.

This research is limited by the choice of the case study method. In the future it would be useful to analyse companies from other countries, in other sectors and with other organisational backgrounds and cultures using the GEN framework. Furthermore, it could be valuable to develop the GEN framework in such a way that managers can use it as an analytical tools wherein to audit and improve their current and future offshore engineering activities. By ensuring capabilities and configuration is aligned as early in the process as possible companies can probably increase the efficiency and effectiveness of engineering offshoring considerably.

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